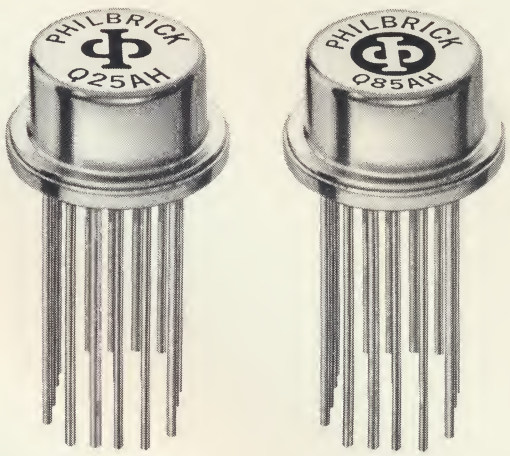
Only Philbrick's New High-Performance Operational Amplifiers can give you...*



PHILBRICK Q25AH PHILBRICK Q85AH

shown twice actual size

Integration Without Compromise

* This is the sort of performance Philbrick required before integrating: Output Range ± 11V @ 2.2 mA; Gain-Bandwidth at least 50 Mcps; Full Output to 100 kcps; Common Mode Range ± 10V; Voltage Gain of 20,000 minimum at rated load; Power Supply ± 15V @ <7 mA; Offset Current < 150 picoamperes (Q25AH).

To get the complete story: phone the nearest Philbrick engineering representative or get in touch with Philbrick Researches, 43-G Allied Drive at Route 128, Dedham, Massachusetts, or

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Engineering Representatives

Ala.: Huntsville 536-8393; **Ariz.:** Phoenix 265-3629; **Cal.:** Los Angeles (213) 937-0780, Palo Alto (415) 326-9800, San Diego 222-1121; **Colo.:** Denver 733-3701; **Conn.:** W. Hartford 233-5503; **Fla.:** Ft. Lauderdale 564-8000, Orlando 425-5505; **Ill.:** Chicago 676-1100; **Ind.:** Indianapolis 356-4249; **La.:** New Orleans 242-5575; **Md.:** Baltimore 727-1999; **Mass.:** Wakefield 245-5100; **Mich.:** Detroit 838-7324; **Minn.:** Minneapolis 545-4481; **Mo.:** Kansas City 381-2122, St. Louis 966-3646; **N.M.:** Albuquerque 268-3941; **N.Y.:** DeWitt (315) 446-0220, Lancaster (716) TF 5-6188, Valley Stream (516) 561-7791; **N.C.:** Winston-Salem 725-5384; **Ohio:** Dayton 298-9964, Westlake 871-8000; **Pa.:** Norristown 735-3520, Pittsburgh 371-1231; **Tex.:** Dallas 526-8316, Houston 781-1441; **Utah:** Salt Lake City 466-4924; **Va.:** Alexandria 836-1800; **Wash.:** Seattle 723-3320; **EXPORT: N.Y.:** New York (212) 246-2133.

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ELECTRONIC ANALOG COMPUTING EQUIPMENT for MODELLING, MEASURING, MANIPULATING and MUCH ELSE

PHILBRICK

PHILBRICK RESEARCHES, INC.

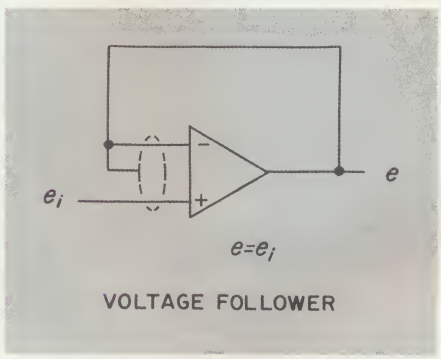
ALLIED DRIVE at ROUTE 128, DEDHAM, MASSACHUSETTS 02026

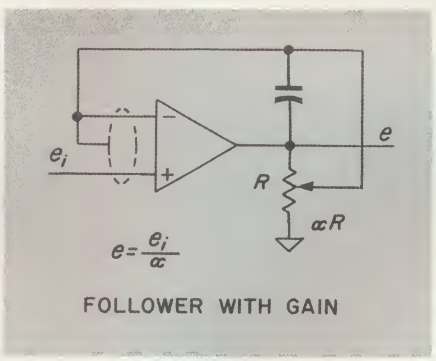
MODEL SP102 HIGH-IMPEDANCE DIFFERENTIAL OPERATIONAL AMPLIFIER

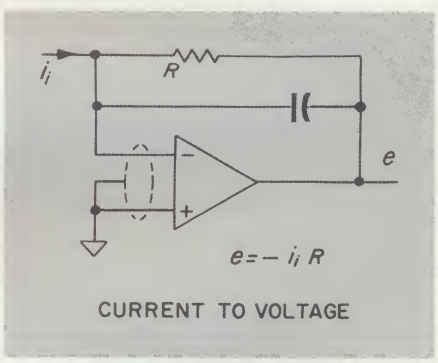
GENERAL DESCRIPTION

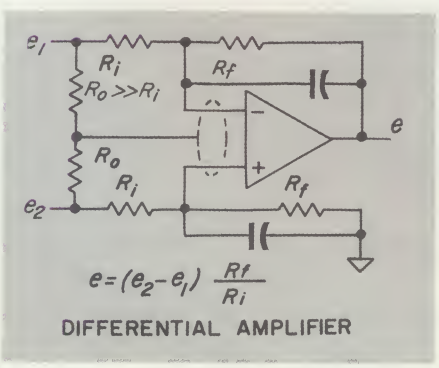
Model SP102 is a member of the family of amplifiers using the unique principle first pioneered ir Philbrick model P2. A radio frequency all-electronic chopper circuit permits extremely high-impedance input circuits to be fully floating with respect to the rest of the amplifier and ground. There is no inherent common mode error, and an insulated guard circuit intercepts stray currents to the input terminals. SP102 combines the properties of electrometer tubes with the voltage resolution of 100 Volt computing circuitry, and the low noise, small voltage offset, minuscule common mode error and insignificant power consumption which to date were only available in low-voltage solid state systems. Here then is an instrument which has the best features of both its high-voltage thermionic and low voltage solid state ancestors, without the disadvantages of either. The astonishingly small input current error was obtained without compromising SP102's voltage stability, which equals that of general-purpose solid state amplifiers. As in other Philbrick plug-in units of recent design, a voltage offset balance control is built in. The exclusive use of best commercial grade components, particularly hermetically sealed silicon semiconductors, conservative circuit design, and an all-embracing quality control program assure the ultimate in reliability and retention of parameters over many years of useful life.

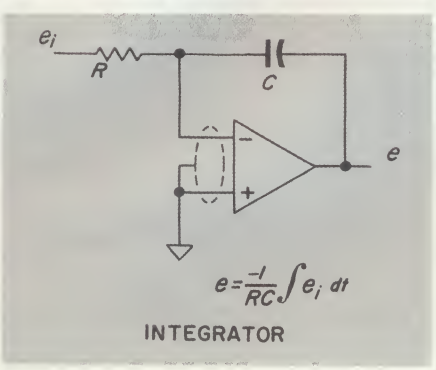
The amplifier is a plug-in module constructed on glass-epoxy etched circuit boards of which one has an edge-connector. A nickel-plated steel case provides electrostatic and magnetic shielding and thermal baffling. A chassis-mounting socket and hold-down hardware are supplied with each amplifier.

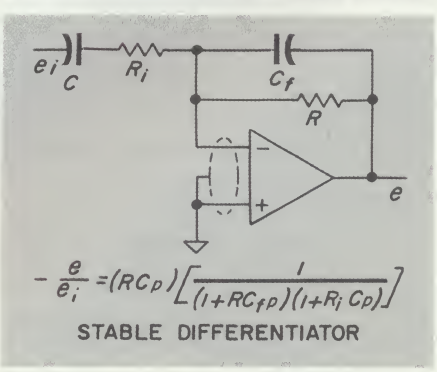












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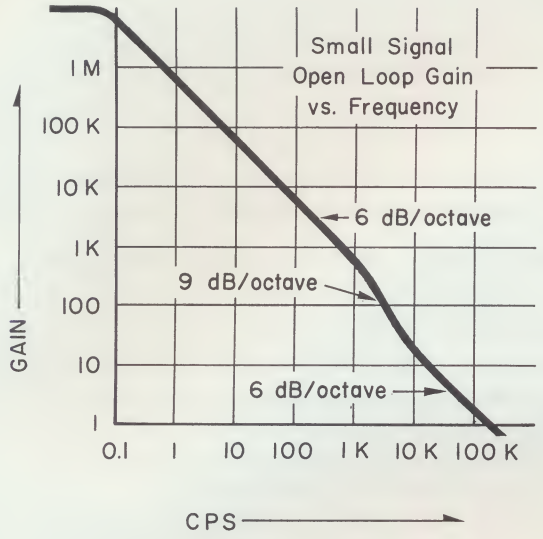
ELECTRICAL CHARACTERISTICS

at 25°C with ±120 V supplies unless stated otherwise.

Parameters	Typical	Worst Case
Voltage Gain, DC Open Loop, Rated (10kΩ) Load	2×10^7	5×10^6
Unloaded	2×10^8	
0-65°C, Rated Load	10^6	10^6
Response, Full Output	150 cps	110 cps
Small-signal unity gain	150 kcps	75 kcps
Output Capability		
Without boost resistors, 50 kΩ load	±101 V	±100 V
With 2 kΩ boost resistors, 50 kΩ load	±104 V	
With 2 kΩ boost resistors, 10 kΩ load	±100 V	
Voltage Offset, referred to Input		
Adjustable with built-in control to	0±20 μV	
Vs. Temperature (0/25/65°C)	3 mV	6 mV
In 24 hours	100 μV	
In 30 minutes	10 μV	
Noise, 1-101 cps RMS	.8 μV	1 μV
Input Current (Voltage Offset Zeroed)	1 pA	10 pA
Vs. Temperature (0/25/65°C)	100 pA	
In 24 hours	.1 pA	
In 30 minutes	.01 pA	
Noise, 1-101 cps RMS	.3 pA	
Input Impedance		
Between Input terminals	10^{10} Ω	
in parallel with	500 pF	
Either Input to Common, without guard	10^{12} Ω	10^{11} Ω
Either Input to Common, with guard	10^{14} Ω	
in parallel with	20 pF	
Power Requirements (±120 V nominal supplies)		
Supply current, Quiescent	±3.6 mA	
Lowest Operating Voltage	±100 V	
Absolute Ratings		
Supply Voltages		±125 V
Between Inputs		15 V
Both Inputs to Common		200 V
Operating Temperature		-25 to +85°C
Storage Temperature		-55 to +85°C

CAUTION:

Without boost resistors, the output of SP102 may be shorted to power common without permanent damage. When boost resistors are used, damage may occur if the short is prolonged beyond one minute at room temperature or ten seconds at +85°C.

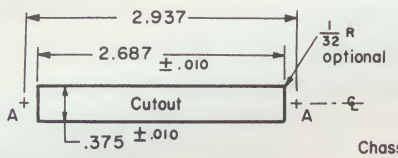


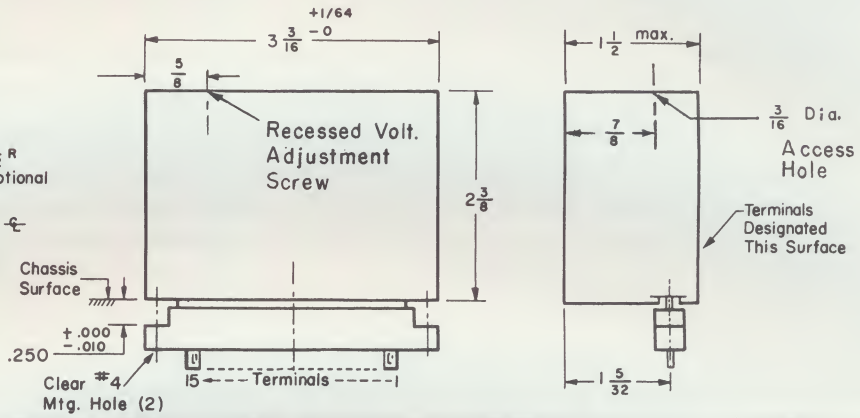
1	OUTPUT	9	KEY
2	-120V SUPPLY	10	NO CONN.
3	+120V SUPPLY	11, 12	-BOOST RESISTOR
4	KEY	13	+BOOST RESISTOR
5	GUARD	14, 15	CASE
6	+INPUT		
7	-INPUT		
8	POWER COMMON		

2kΩ boost resistors (supplied) connect between terminals 3 & 13 and 11 & 12

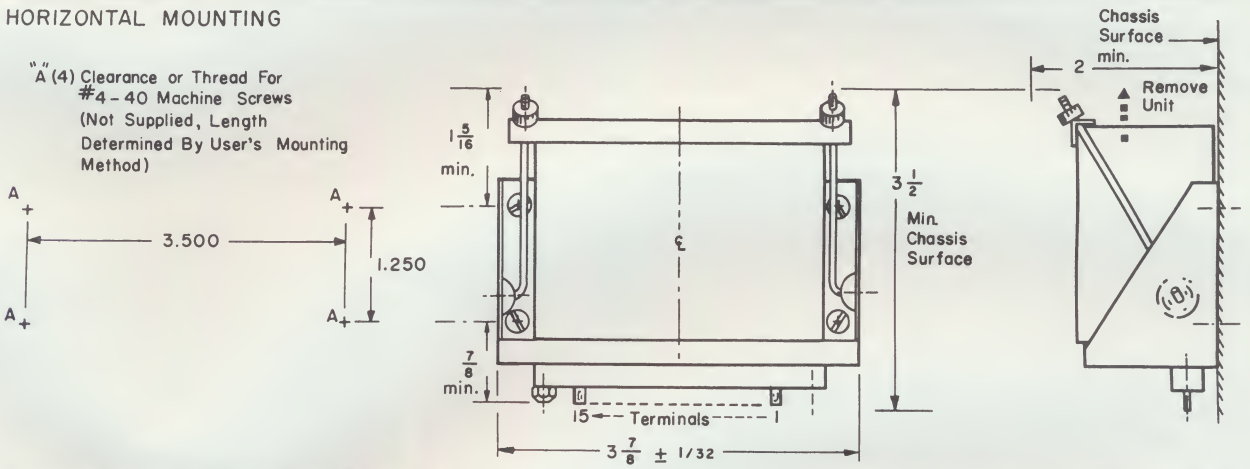
TERMINAL CONNECTIONS

CHASSIS MOUNTING PATTERN

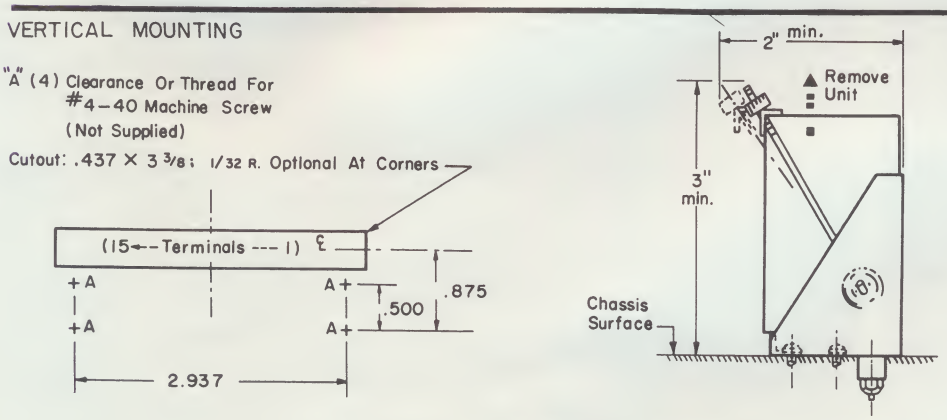




HORIZONTAL MOUNTING



VERTICAL MOUNTING



Note
1. Connector Supplied.
2. Mounting Bkt. Steel, .036 Th'k.
3. Connector Is Floating When Mounted To Bracket. DO NOT ATTEMPT TO TIGHTEN CONNECTOR MOUNTING SCREWS

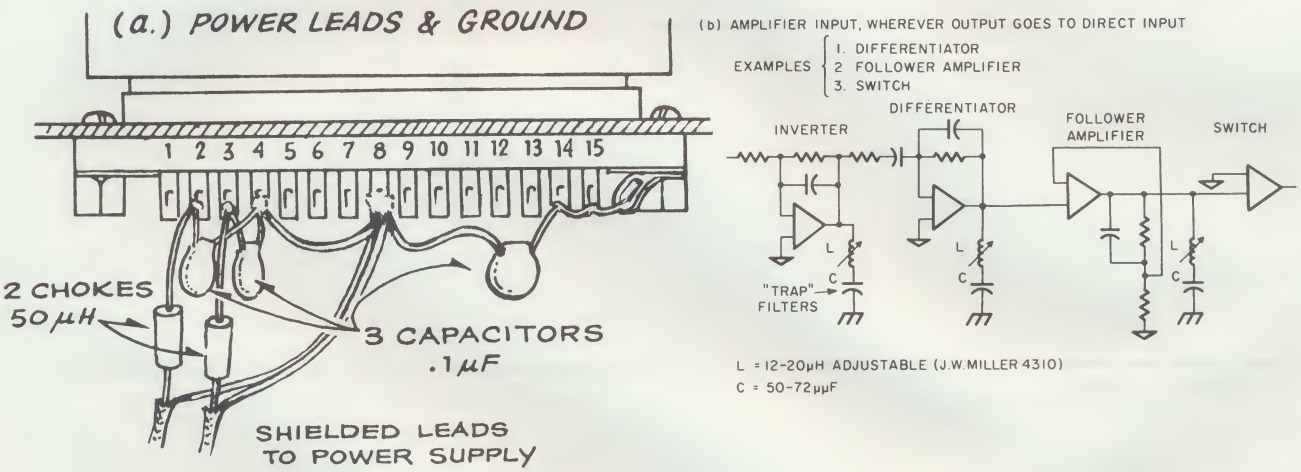
OUTLINE & MOUNTING DIMENSIONS

Grounding

The case of SP102 terminals 14 and 15, must always be grounded to chassis, e.g. through a lug under a socket mounting screw. Terminal #8 is always connected to the common terminal of the power supply. When only one amplifier is used, and the power supply common is at chassis potential, a jumper between pins 8 and 14 completes the ground system. If, however, several amplifiers are used together, ground loops created in this manner may result in undesired coupling and interaction. Separate leads from terminal #8 of each amplifier to the power supply and 0.1 μF or larger capacitors between pins 8 and 14 of each amplifier will prevent ground loops.

Decoupling

A small noise voltage at the chopper frequency of approximately 5 Mcps may be present at various amplifier terminals. In systems with several SP102 amplifiers, this may give rise to cross-talk and beat-frequency interference, requiring a few simple precautions. 0.1 μF capacitors across the supply terminals (2 to 8 and 3 to 8) directly on each SP102 socket, and separate, preferably shielded power leads from each amplifier to the power supply, are generally adequate. If this is not sufficient, and other causes have been eliminated by studying each SP102 circuit separately (others disconnected), a 50 μH choke with less than 1.5 Ω resistance may be inserted in each supply lead at terminals 2 and 3 of each amplifier socket. If SP102's are used as differentiators, or if the input of one is directly connected to the output of another, a trap or a pair of fundamental and harmonic traps may be used as shown below. These chokes and traps do not affect operation within the normal pass band.



Warranty and Repair

Philbrick products are warranted against defects in materials and workmanship for two years after date of shipment. During this period Philbrick will repair or replace defective amplifiers free of charge. Electrical or mechanical abuse or removal from the sealed case will void this warranty. For products on which the warranty has expired or voided, the Philbrick repair service is available at a reasonable charge. For details see "A Directory on How to Do Business with Philbrick and the Services Offered".

PHILBRICK RESEARCHES

Model MP Self-Powered 4-Amplifier Operational Manifold

GENERAL DESCRIPTION

Model MP is a self-contained analog instrument for research, development, industrial control, simulation and teaching. More versatile than its vacuum tube predecessor Model MK, the new Philbrick self-powered fourfold Model MP fully exploits the high reliability, small size, low drift and noise, light weight and low power requirements of available all-silicon solid state amplifiers to achieve the greatest possible flexibility of application and a degree of accuracy which heretofore could be achieved only at much higher cost.

Model MP contains four amplifiers chosen from the family of mechanically identical Philbrick type P plug-in units, a Philbrick Model OSPR-30 power supply, a jack panel on which circuitry may be conveniently assembled, and a pair of accessory sockets for Philbrick SP-size plug-in units.

DESIGN FEATURES

The Amplifiers

Model MP is normally equipped with four P65AU general purpose amplifiers. While no other amplifier provides so much all-round performance per dollar, more sophisticated requirements can be met by choosing in any permutation or combination specialized high-performance amplifiers. To name a few:

- P25A for extremely high input impedance and sub-nanoampere current offsets. (FET type)
- P35A for lower voltage offset drift, low input currents, and high common mode rejection.
- P45AL for greater output current capability and stability under capacitive loading.
- P65AH for full output up to 80 kc/s and rapid switching.
- P75A for low input currents at low cost.
- P85A for high common mode rejection and low voltage offset.

For comparative characteristics see the latest Philbrick Solid State Amplifier Chart. Utility grade equivalents, denoted by the letter U following the model designation, are or will be available for several of these amplifiers. At room temperature these provide identical performance at greatly reduced cost.

The Power Supply

Philbrick Model OSPR-30 is a compound regulated power supply. Output voltages are ±15 VDC with .05% regulation under all conditions of line (115 ±10 volts) and load (0-30 milliamps) at room temperature. This supply is adequate for one amplifier capable of and delivering 20 milliamps output, plus three amplifiers supplying load currents under two milliamps. If none of the four amplifiers supplies more than two milliamps, adequate power is available for a variety of accessories or external amplifiers. The power supply voltages are brought out to separate jacks on the panel for availability as input or reference voltages. A captive line cord is used. The dual primary windings of the power transformer can be connected for a 230 volt line on special order.

The Interconnection Panel

Amplifier input, output and common terminals are brought out to multiple tip jacks on the sloping front panel. Jacks are spaced on a pattern of equilateral triangles, permitting the use of twin tip plugs with 3/4" spacing as convenient mounting for passive components, as shorting bars, and as terminations for shielded input and output cables. Jacks are color coded and their functional interconnections with the amplifiers are indicated on the panel. A full line of connecting hardware is commercially available; Philbrick can supply an "Accessory Kit", Model MAK, containing all items of connecting hardware normally required. Also available is a "Computing Component Starter Kit", Model CCK, containing a selection of resistors, capacitors and diodes in the values required for most common applications. The contents of these kits are listed in an appendix hereto.

The Accessory Sockets

Two 15-contact edge connector sockets are accessible through an opening in the back of Model MP. They are primarily intended to permit the use of Philbrick standard non-linear plug-in components such as Model PSQ Quadratic Transconductors, for which the operational connections are brought out to separate jacks on

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the panel. Uncommitted Philbrick plug-in units permit the user to build his own special-purpose assemblies. The unenclosed circuit card with 15-contact edge connector bears the designation OSP-0. Enclosed in a nickel plated steel case it is listed as SP-0. Either version offers a useful circuit area of 2 x 3 inches. Components may rise one inch above the board surface.

To accommodate input signals in the microvolt or picoampere range, it is possible to wire the accessory sockets for Philbrick SP65A or SP2A amplifiers, respectively. This is a simple soldering operation, for which instructions are available on request.

APPLICATIONS

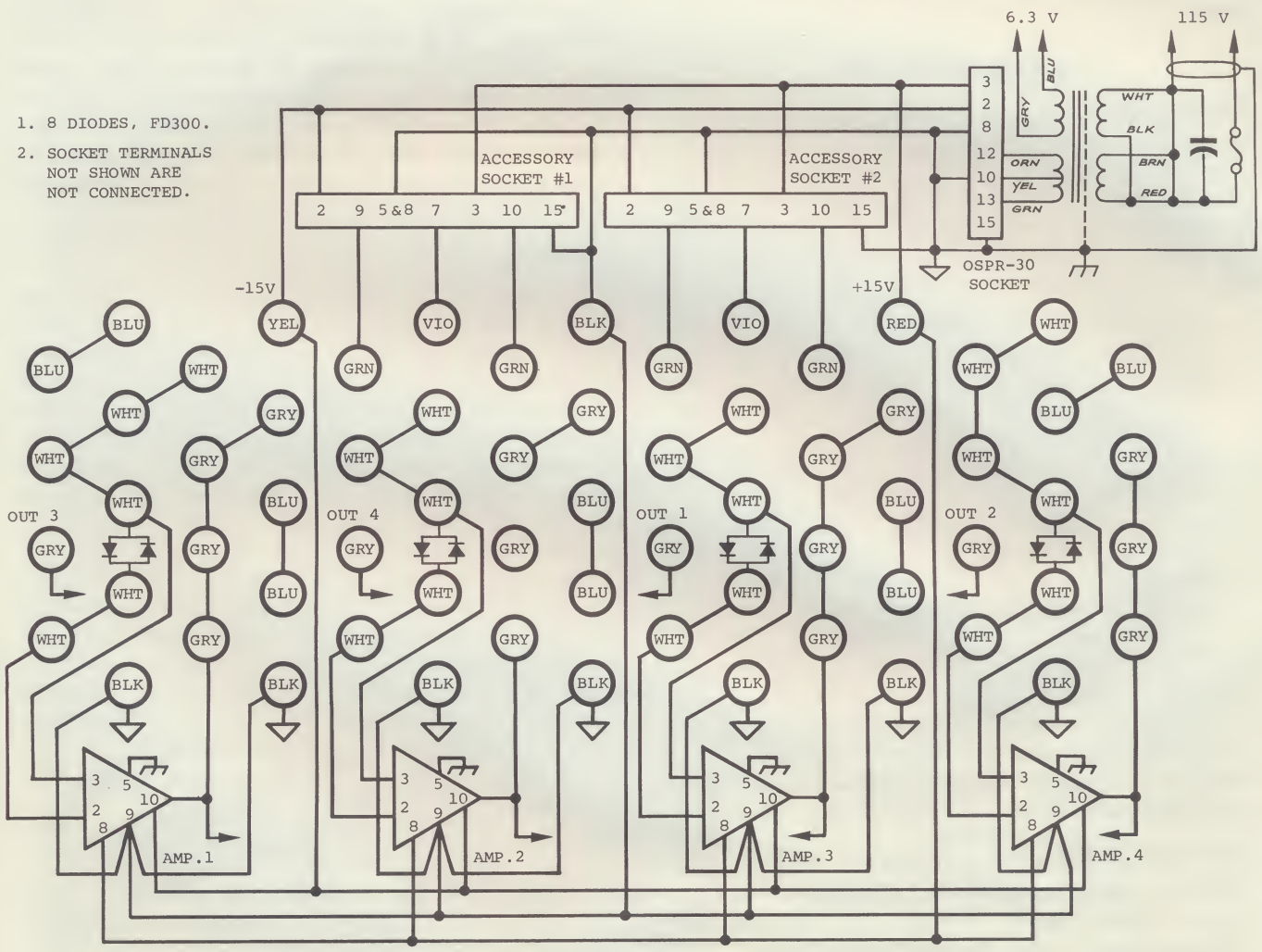
The jack panel configuration is designed to facilitate easy building and experimenting with a wide variety of circuit configurations involving one or more amplifiers by plugging in passive components and leads to signal source and read-out or load. A few relevant examples of multi-amplifier circuits are included herein. Naturally, a good number of the circuit structures described in Philbrick's many applications publications can be embodied in Model MP. Furthermore, Philbrick is delighted to discuss with users the properties of any comtemplated circuit of particular interest. The Philbrick Applications Department and your local Philbrick Representative will welcome your inquiry.

Any of these applications assumes that the amplifiers used have impedance levels and common mode rejection appropriate to the application and that each amplifier has been carefully balanced for zero voltage offset by adjustment of its built-in balance control. To balance any one amplifier, connect its positive input to common, install a 100Ω resistor from negative input to common, and a 10kΩ resistor in parallel with a 100pF capacitor between the negative input and output. Allow the circuit to reach thermal equilibrium (30 minutes with power applied is recommended) and adjust the balance control for zero output. In most applications one need check proper balance no more often than weekly.

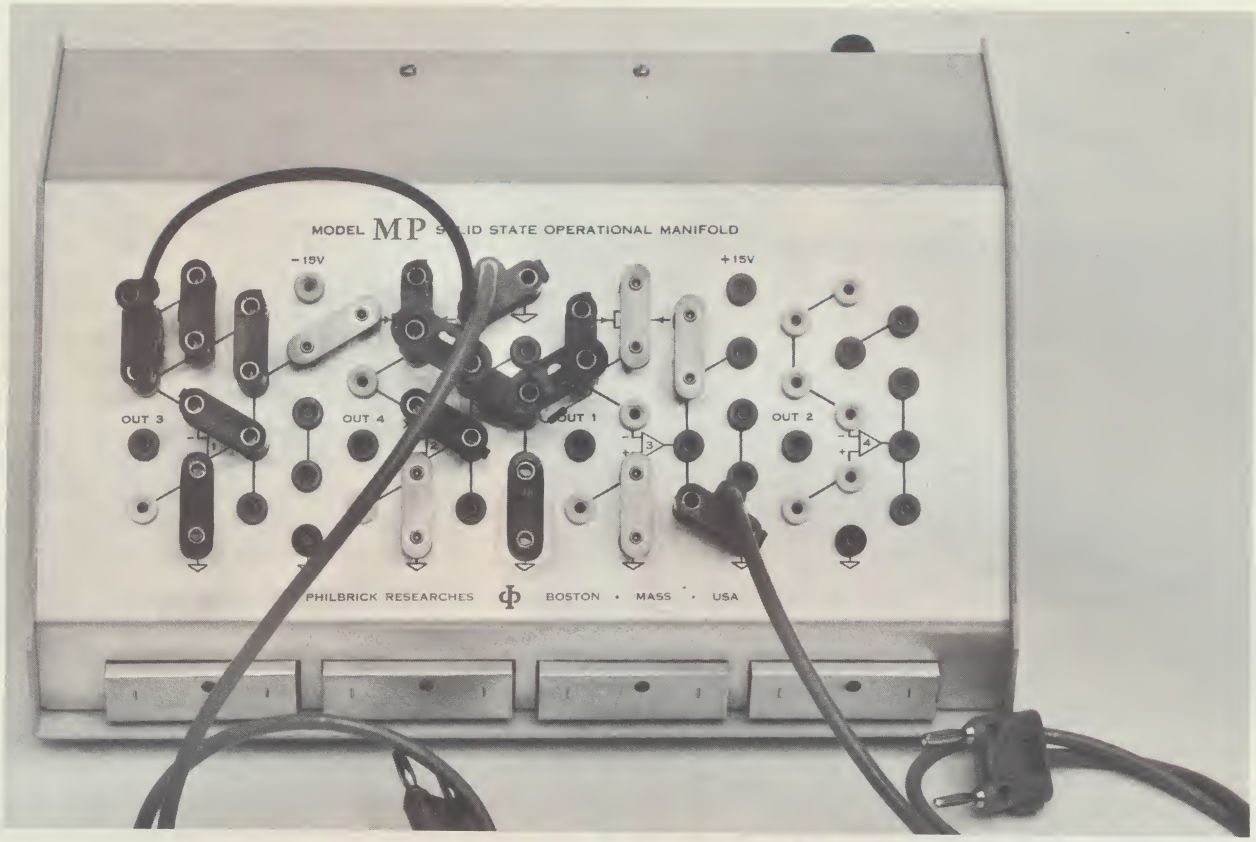
CONSTRUCTION

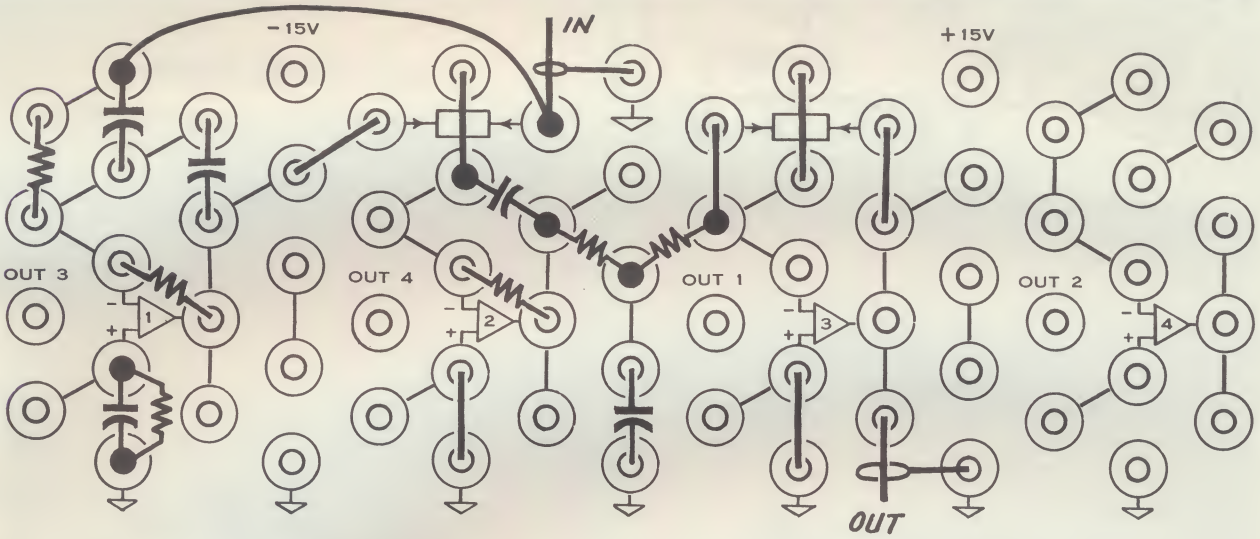
Though designed for versatility and low cost. Model MP is sturdily built, attractively packaged, and wired to Philbrick's usual high standards of quality. The simple sheet-aluminum enclosure with clear iridite finish provides effective shielding and solid mounting of electrical components.

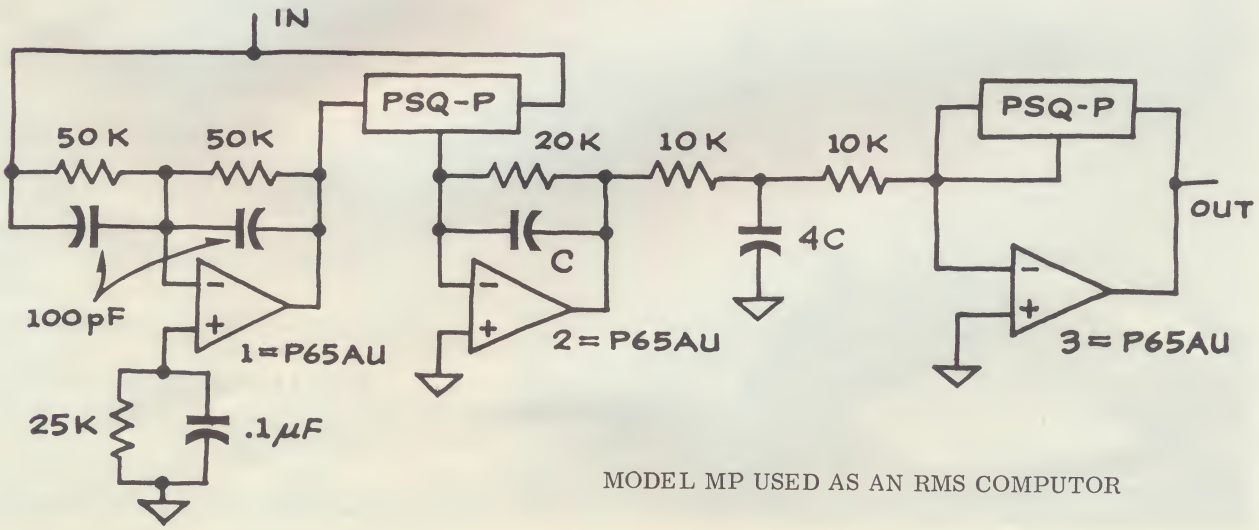
Dimensions: 11-3/4" wide, 7-1/8" deep, 5-3/4" high.
Weight, including all plug-ins: net approx. 5 lbs.
packed approx. 7 lbs.



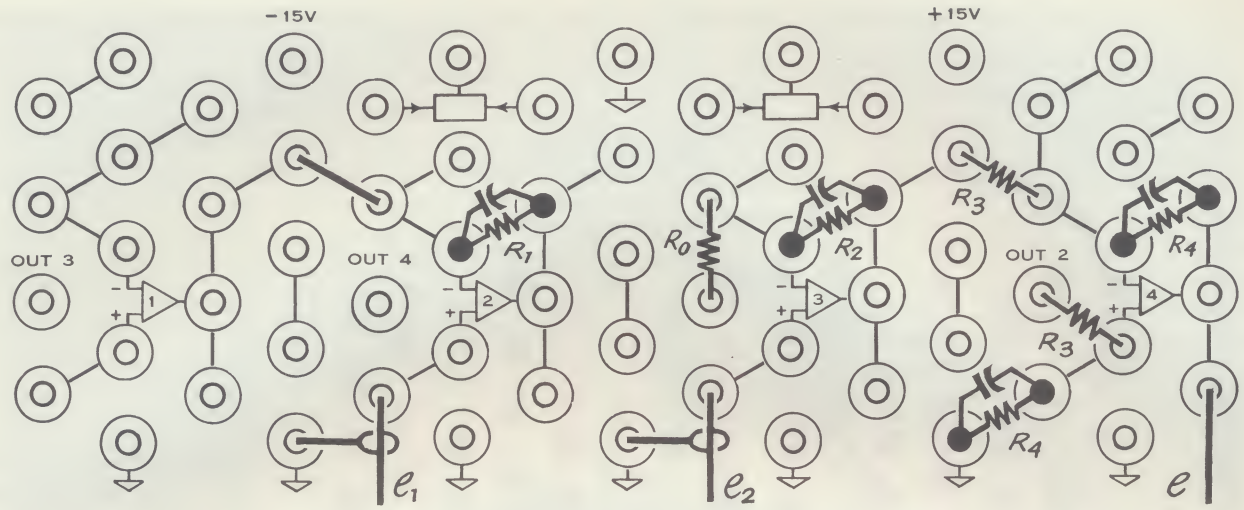
MODEL MP SCHEMATIC DIAGRAM

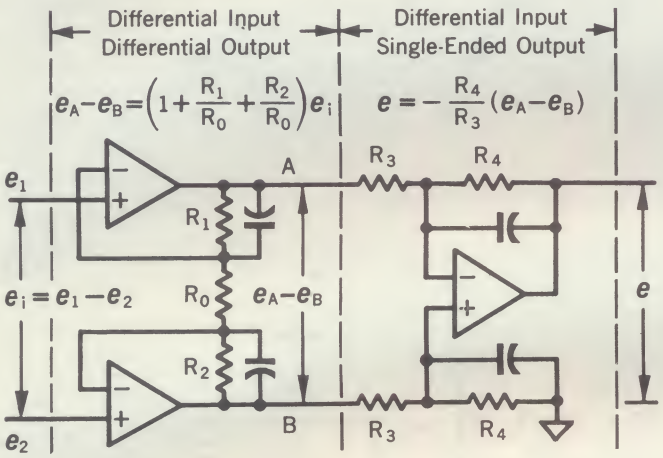






MODEL MP USED AS AN RMS COMPUTOR





MODEL MP USED AS A
DIFFERENTIAL INSTRUMENT AMPLIFIER

MODEL MP REAR VIEW

GEORGE A.
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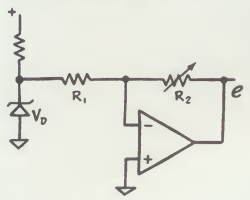
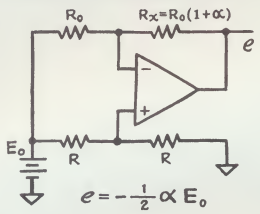
TYPICAL OPERATIONAL AMPLIFIER CHARACTERISTICS
for MODELLING, MEASURING, MANIPULATING, and MUCH ELSE

PRECISION VARIABLE VOLTAGE SOURCE



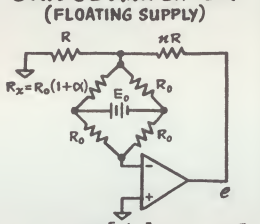
$e = -V_D \frac{R_2}{R_1}$

BRIDGE AMPLIFIER (ACTIVE BRIDGE, ULTRALINEAR)



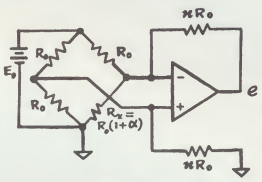
$e = -\frac{1}{2} \alpha E_0$

BRIDGE AMPLIFIER (FLOATING SUPPLY)



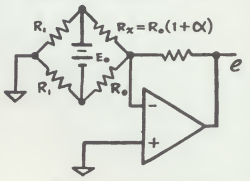
$e = (1+n) \alpha \frac{E_0}{4} \left[\frac{1}{1+\frac{\alpha}{2}}\right] \cong (1+n) \alpha \frac{E_0}{4}$

BRIDGE AMPLIFIER (ONE END GROUNDED)



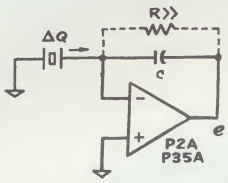
$e = -\frac{n}{2} \frac{E}{1+\frac{1}{2n}} \frac{\alpha}{1+\alpha} \cong -\frac{n}{2} \frac{E}{1+\frac{1}{2n}} \alpha$

BRIDGE AMPLIFIER (MID-POINT GROUNDED)



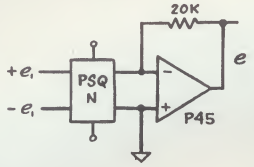
$e = \frac{E_0}{4} n \alpha \left[\frac{1}{1+\frac{\alpha}{2}}\right] \approx \frac{E_0}{4} n \alpha$

CHARGE AMPLIFIER



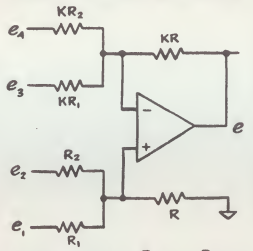
$-e = \frac{\Delta Q}{C}$

PRECISE WIDE BAND SQUARER



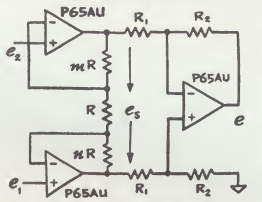
$e = \frac{1}{10} e_1^2$

ADDING SUBTRACTOR



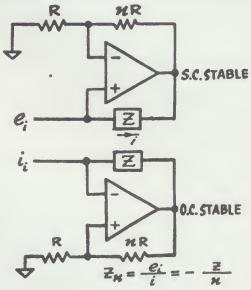
$e = \frac{R}{R_1} e_1 + \frac{R}{R_2} e_2 - \frac{R}{R_1} e_3 - \frac{R}{R_2} e_4$

LOW-COST, LOW-NOISE HIGH-INPUT IMPEDANCE DIFFERENTIAL-TO-SINGLE-ENDED AMPLIFIER



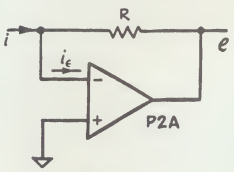
$e_s = (1+m+n)(e_1 - e_2)$
$e = \frac{R_2}{R_1} e_s$

NEGATIVE IMPEDANCES



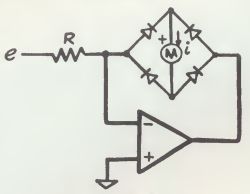
$Z_N = \frac{e_i}{i} = -\frac{Z}{n}$

CURRENT-TO-VOLTAGE TRANSRESISTOR



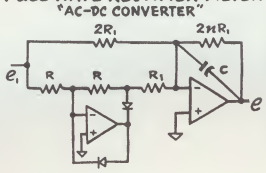
$e = iR$
$i_\epsilon < 10^{-11}$ amp
$i_{NOISE} < 10^{-13}$ amp

PRECISION AC-DC CONVERTER (METER OUTPUT)



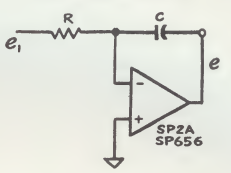
$i = \left|\frac{e}{R}\right|$

PRECISION FULL-WAVE RECTIFIER-FILTER "AC-DC CONVERTER"



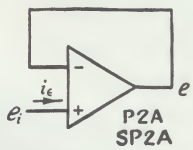
$e = n \left|e_1\right| \left[\frac{1}{1+2R_2Cp}\right]$

STABLE INTEGRATOR



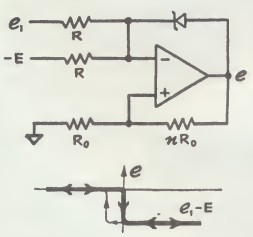
$-e = \frac{1}{RC} \int e_1 dt$
$\left.\frac{de}{dt}\right|_{error} < \frac{10^{-11}}{C}$

FOLLOWER (ELECTROMETER)

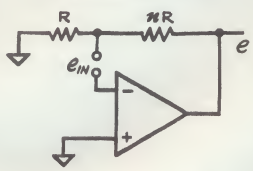


$e = e_i$
$i_\epsilon < 10^{-11}$ amp
$i_{NOISE} < 10^{-13}$ amp

PRECISE VOLTAGE OR CURRENT COMPARATOR WITH HYSTERESIS

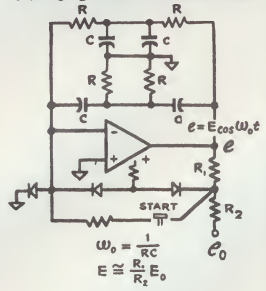


FLOATING SOURCE PREAMPLIFIER



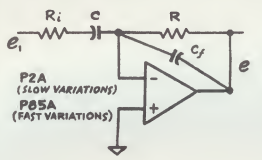
$e = (1+n) e_{IN}$

PRECISION OSCILLATOR



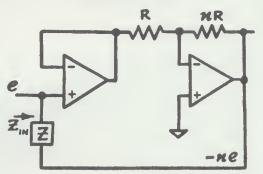
$\omega_0 = \frac{1}{RC}$
$E \cong \frac{R_1}{R_2} E_0$

STABLE LOW-NOISE DIFFERENTIATOR



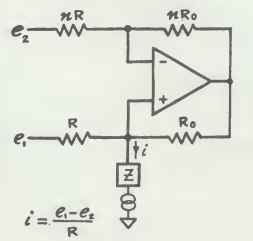
$-\frac{e}{e_i} = \left[RCp\right] \left(\frac{1}{(1+RC_fp)(1+R_iCp)}\right)$

IMPEDANCE SCALER



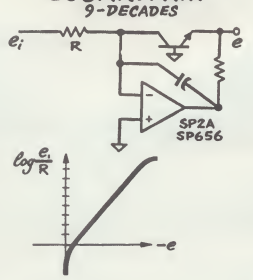
$i_{IN} = \frac{(1+n)e}{Z}$
$Z_{IN} = \frac{Z}{1+n}$

VARIABLE CONTROLLED CURRENT SOURCE

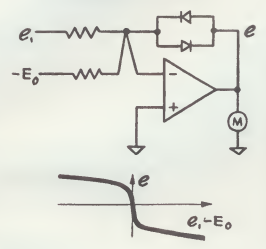


$i = \frac{e_1 - e_2}{R}$

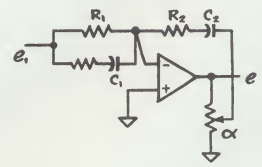
PRECISE WIDE-RANGE LOGARITHM 9-DECADES



GRADED NULL MEASUREMENT

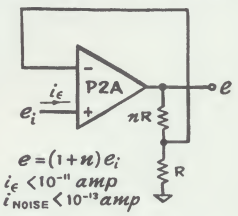


CONTROLLER (3-TERM)



$-\frac{e}{e_i} = \frac{1}{\alpha} \frac{R_2}{R_1} \left(1+\frac{1}{R_2C_2p}\right) \left(1+R_1C_1p\right)$
PROPORTIONAL INTEGRAL DERIVATIVE

FOLLOWER WITH GAIN (ELECTROMETER AMPLIFIER)



$e = (1+n) e_i$
$i_\epsilon < 10^{-11}$ amp
$i_{NOISE} < 10^{-13}$ amp

For information on any of the circuits shown here consult PHILBRICK or their representative nearest to you.

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